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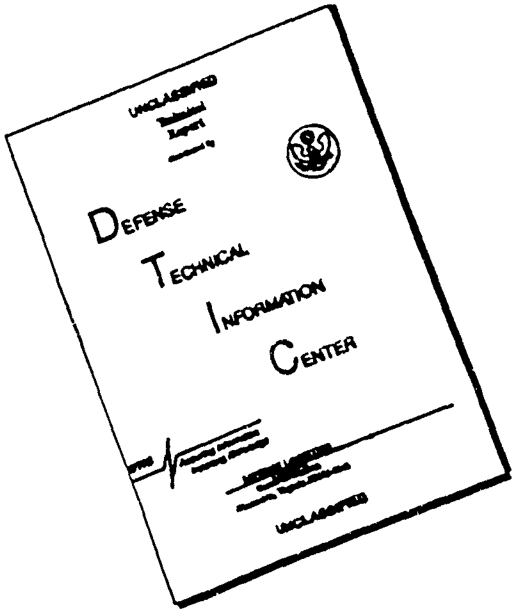

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July 19, 1961
DMIC Memorandum 116

GENERAL RECOMMENDATIONS ON DESIGN FEATURES FOR TITANIUM AND ZIRCONIUM PRODUCTION-MELTING FURNACES

Prepared by a Committee Representing

Allegheny Ludlum Steel Corporation
Crucible Steel Corporation
Reactive Metals, Inc.
Republic Steel Corporation
Titanium Metals Corporation of America

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COLUMBUS 1, OHIO

FOREWORD

The design of commercial melting units, with special emphasis on the incorporation of desirable safety features, has been a subject of considerable interest to those involved in the production of titanium and zirconium. In order to arrive at some general recommendations for the benefit of the industry, representatives of five of the larger producers formed an informal joint working committee on safety practices. These five producers are:

Allegheny Ludlum Steel Corporation
Crucible Steel Corporation
Reactive Metals, Incorporated
Republic Steel Corporation
Titanium Metals Corporation of America

The committee has just released an outline of recommendations on design features for titanium- and zirconium-melting furnaces. In order to make this information more generally available, and with the approval of the committee, this outline is reproduced in this memorandum. Publication in this form does not necessarily imply DMIC concurrence with each of the specific recommendations.

RECOMMENDATIONS ON DESIGN FEATURES FOR CONSUMABLE-ELECTRODE, ARC FURNACES 12" AND LARGER FOR MELTING TITANIUM AND ZIRCONIUM

1.0 General

1.1 The water supply for cooling should be protected in the form of a standpipe reserve, auxiliary supply, or auxiliary pumps driven by steam, diesel, etc. The standby cooling system should be incorporated to provide a reserve of cooling water to cool down the furnace adequately in the event of a failure in the primary water supply. The standby water supply system should not be used for melting, and instrumentation should be provided to indicate its serviceable condition. See attached sketch of typical cooling water system.

2.0 Furnace Design Practices for Cold-Mold Melting of Titanium or Zirconium

2.1 Over-All Construction

2.1.1 There should be positive protection for all personnel. This protection may consist of a suitable barricade or a test cell of the vault-type design such as is used for testing jet or rocket engines. The vault type should have a weak side to relieve internal pressure in a direction away from the location of all personnel. See sketch of typical vault type construction employed.

2.1.2 Furnace assemblies and components should be visually checked periodically for soundness of the structure. A positive mechanical clamping system rather than vacuum alone should be used to maintain assembly of the furnace components during the melting operation.

2.1.3 The furnace should be equipped with a relief device such as a rupture disc to aid in releasing pressure in a safe manner should a water leak develop inside the furnace. Means should be provided to prevent reflux of air through the pressure relief port. The release pressure for the rupture disc should be set at slightly above the maximum water pressure in the furnace jacket.

2.1.4 The exhaust side of vacuum pumps should be vented in a safe manner to the outside of the building to prevent accumulation of hydrogen.

2.2 Crucibles or Molds

2.2.1 If water is used for cooling, adequate clearance between the consumable electrode and crucible sidewall should be maintained: Minimum clearance should be two and one-half to three inches. It appears

that the safety of the melting operation may be increased by shortening the arc gap. This should reduce the tendency to arc to the crucible wall. The materials being melted, the geometry of the furnace, the geometry of the consumable electrode, the melting rate, the current, the pressure, and many other factors affect the length of the arc gap. In general, furnaces should be operated in a manner so that the arc length does not exceed the minimum distance between the electrode and the crucible side wall.

2.2.2 Electrode Alignment: The furnace should be equipped with an internal guide for sponge electrodes to assure clearances as stated in 2.2.1.

2.2.3 Magnetic Arc-Focusing Coil: The furnace should be equipped with a magnetic arc-focusing coil. The coil should extend the full length of the melting zone. The desired field strength supplied by the coil is dependent upon operating conditions.

2.2.4 Bottom Construction: The copper bottom plate should be at least 2 inches thick if the arc is started by contact of the electrode with a precharge. If a thinner bottom plate is used, the arc should be started with a high-frequency spark generator, or starting tab.

2.2.5 Sidewall Construction: The sidewall should consist of a weldable grade of deoxidized copper that is at least 1/2-inch thick.

2.2.6 Flanges: The flanges should be made of a nonmagnetic material or designed so that magnetic flux concentrations are avoided.

2.2.7 Construction Methods: All components should be shielded-inert-gas-metal-arc consumable-electrode welded, preferably by automatic welding machines.

2.2.8 Electrical Connections: The current should be introduced at the bottom of the crucible to avoid undesirable magnetic effects on arc stability.

2.2.9 Crucible Supports: Adequate supports should be provided to the crucible so that the sidewall alone does not carry the total weight of the ingot.

2.2.10 Tests, Inspection: The crucible components should be cleaned and inspected after each melt. The assembled crucible should be visually inspected for soundness and vacuum checked for leak tightness prior to every melt.

2.2.11 Method of Cooling: Flow of water should be directed tangentially at a minimum velocity of one foot per second. Water pressure on the crucible should be held to a minimum.

2.2.12 Undesirable Magnetic Effects: Avoid placement of high-current leads and furnace structures in a manner that results in distortion of the magnetic field of the arc that influences the stability of the arc adversely.

3.0 Furnace Instrumentation

The following minimum amount of instrumentation is recommended to protect a melting furnace and its operating personnel:

3.1 Interlocks That Shall Prevent or Stop Power to the Arc

3.1.1 Automatic device that senses lack of discharge of water from the crucible water jacket.

3.1.2 Automatic device that senses that pressure inside the crucible is excessive. Power cut off should occur at a set gage pressure but never higher than five pounds per sq. inch.

3.1.3 Manual shutdown buttons at suitable locations.

3.2 Warning Devices

3.2.1 Detect personnel attempting to enter the furnace vault during the melting operation.

3.2.2 Detect excessive crucible cooling water outlet temperature.

3.2.3 Detect excessive electrode shaft water outlet temperature.

3.2.4 Detect when limits of electrode travel have been reached.

3.2.5 Detect failure of cooling system on power leads.

3.2.6 Detect failure in water pressure.

3.2.7 Detect failure of DC power used for melting.

3.2.8 Detect power failure to the magnetic arc-focusing coil.

3.2.9 Detect failure of power to the vacuum pumping system or loss of vacuum.

3.2.10 Detect lack of discharge of water from the electrode shaft.

3.3 Visual Observation and/or Recording Instruments

3.3.1 Arc voltage

3.3.2 Arc current

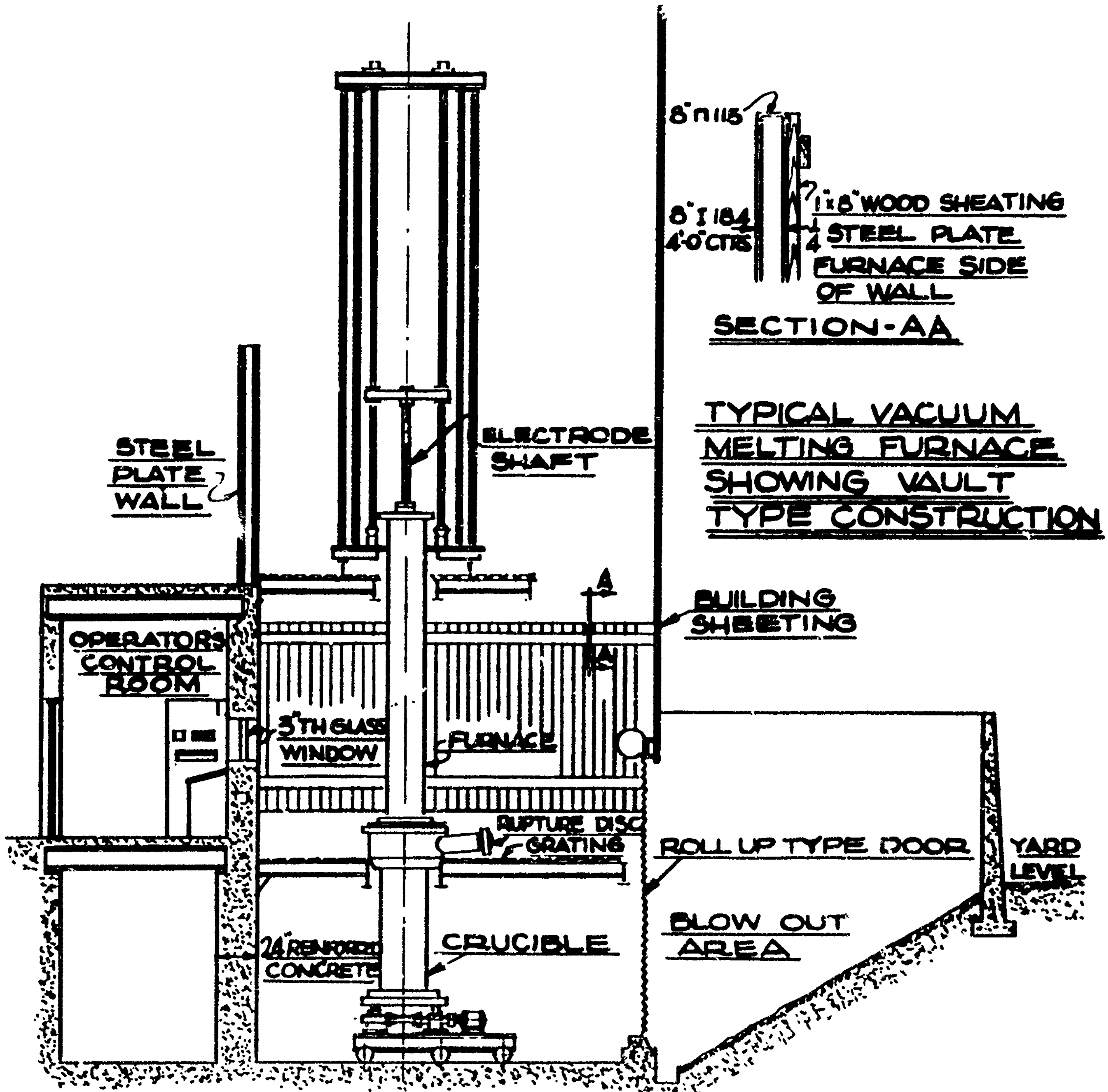
3.3.3 Pressure in the crucible

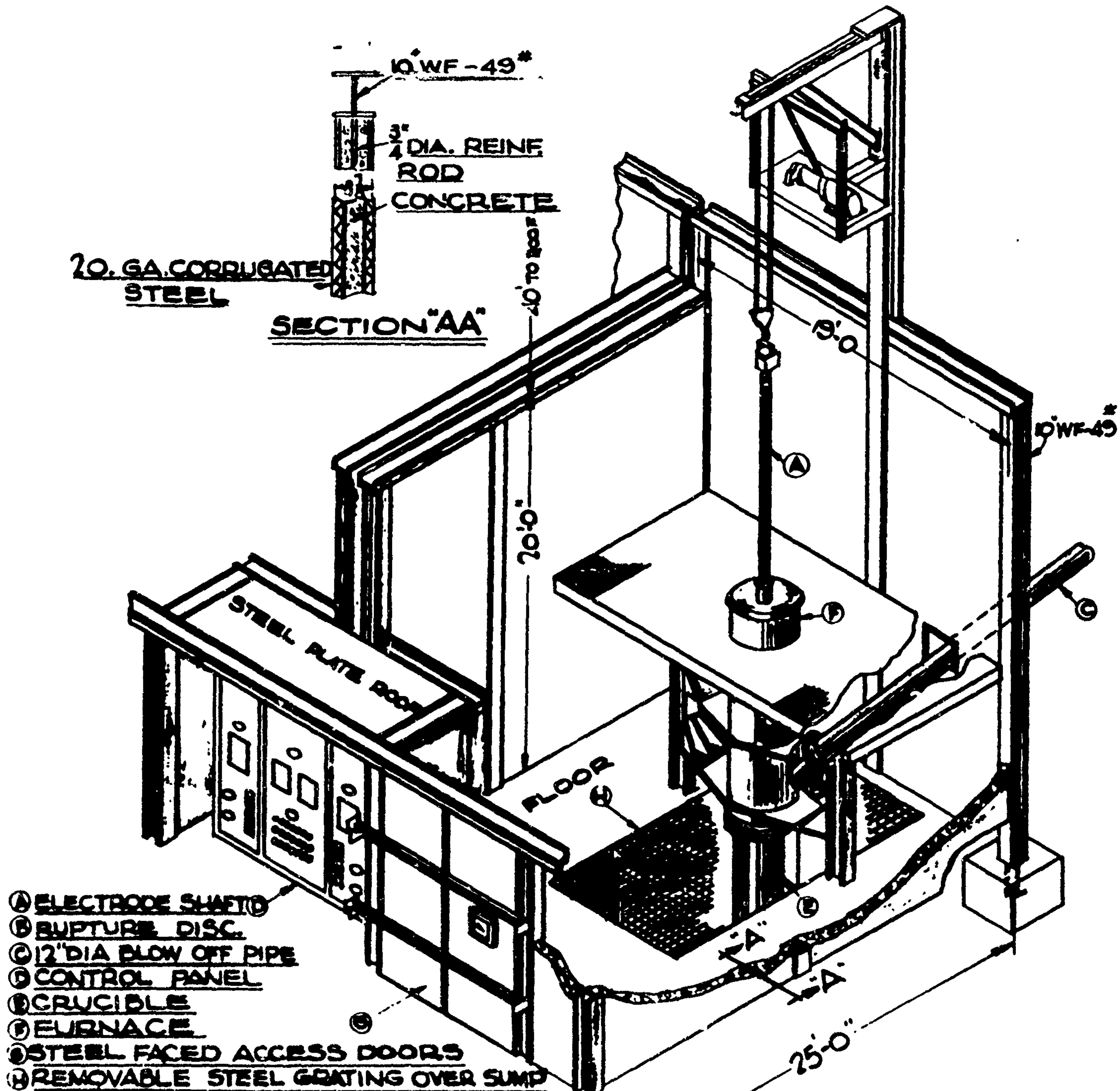
3.3.4 Position of the electrode

3.3.5 Elapsed time

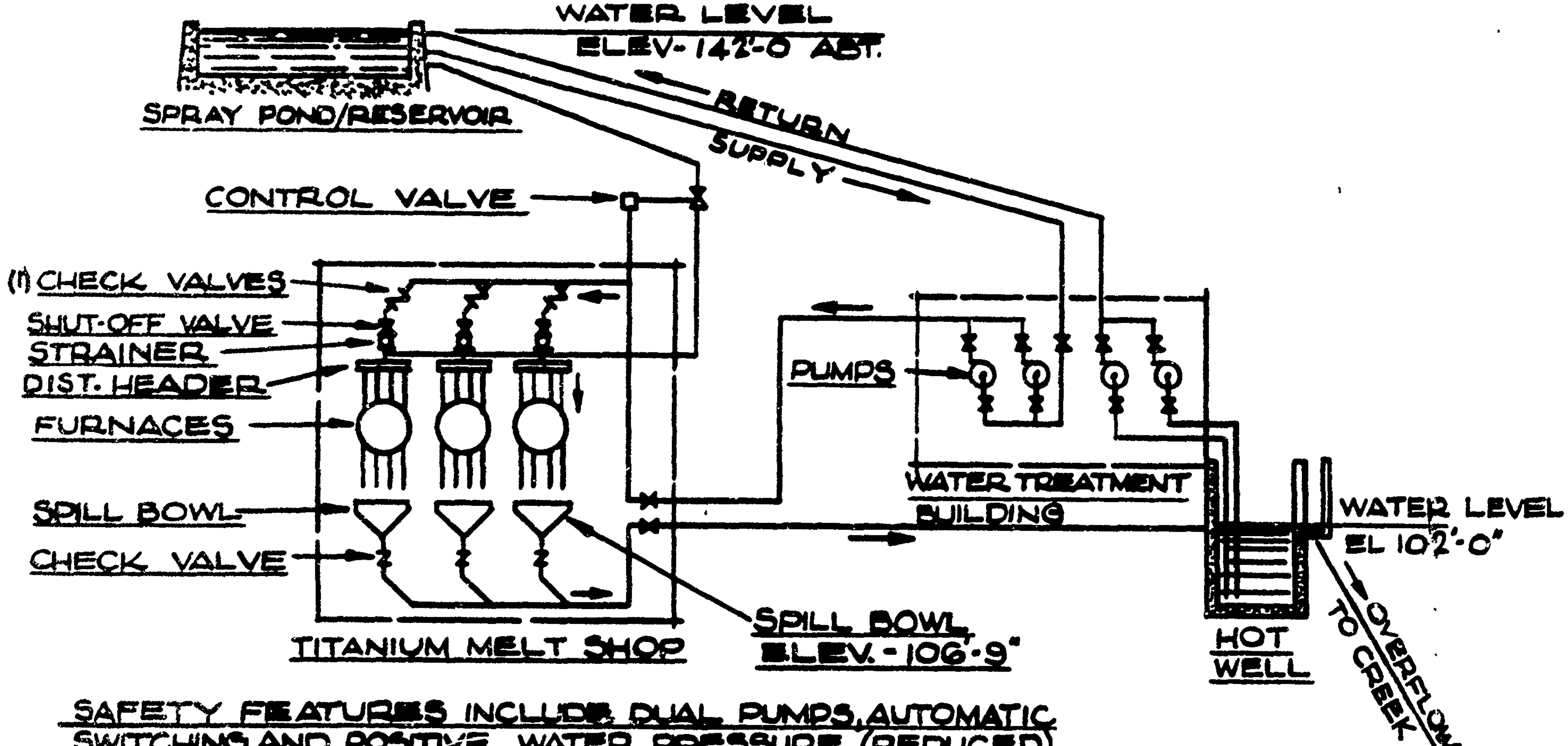
3.3.6 Current on the magnetic arc-focusing coil

3.3.7 Glow discharge indicator


8" n 11.5
8" I 18.4
4'-0" CTRS
1x8" WOOD SHEATING
1/4 STEEL PLATE
FURNACE SIDE OF WALL
SECTION-AA
TYPICAL VACUUM MELTING FURNACE SHOWING VAULT TYPE CONSTRUCTION
STEEL PLATE WALL
ELECTRODE SHAFT
BUILDING SHEETING
OPERATORS CONTROL ROOM
3" TH GLASS WINDOW
FURNACE
RUPTURE DISC
GRATING
ROLL UP TYPE DOOR
YARD LEVEL
BLOW OUT AREA
24" REINFORCED CONCRETE
CRUCIBLE
A
A



TYPICAL VACUUM MELTING FURNACE SHOWING VAULT TYPE CONSTRUCTION



SAFETY FEATURES INCLUDE DUAL PUMPS, AUTOMATIC SWITCHING AND POSITIVE WATER PRESSURE (REDUCED) IN CASE OF PUMP FAILURE

(1.) CHECK VALVES IN MAIN COOLING WATER LINES TO PREVENT EMERGENCY COOLING WATER LOSS THROUGH BROKEN HEADER, ETC.

TYPICAL SCHEMATIC OF PLANT COOLING WATER SYSTEM FOR TITANIUM MELTING

LIST OF DMIC MEMORANDA ISSUED (CONTINUED)
DEFENSE METALS INFORMATION CENTER
Battelle Memorial Institute
Columbus 1, Ohio

Copies of the technical memoranda listed below may be obtained from DMIC at no cost by Government agencies and by Government contractors, subcontractors, and their suppliers. Others may obtain copies from the Office of Technical Services, Department of Commerce, Washington 25, D. C. (See PB numbers and prices in parentheses).

A list of DMIC Memoranda 1-61 may be obtained from DMIC, or see previously issued memoranda.

DMIC Memorandum Number	Title
62	Effects of Rate of Heating to Aging Temperature on Tensile Properties of Ti-2.5Al-16V Alloys, August 18, 1960, (PB 161212 $0.50)
63	Notes on Large-Size Electrical Furnaces for Heat Treating Metal Assemblies, August 25, 1960
64	Recent Developments in Superalloys, September 8, 1960, (PB 161214 $0.50)
65	Compatibility of Rocket Propellants with Materials of Construction, September 15, 1960, (PB 161215 $0.50)
66	Physical and Mechanical Properties of the Cobalt-Chromium-Tungsten Alloy WI-52, September 22, 1960, (PB 161216 $0.50)
67	Development of Refractory Metal Sheet in the United States, September 20, 1960, (PB 161217 $0.50)
68	Some Physical Properties of Martensitic Stainless Steels, September 28, 1960, (PB 161218 $0.50)
69	Welding of Columbium and Columbium Alloys, October 24, 1960, (PB 161219 $0.50)
70	High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy, October 27, 1960, (PB 161220 $0.50)
71	Explosive Metalworking, November 3, 1960, (PB 161221 $0.50)
72	Emissivity and Emittance--What are They?, November 10, 1960, (PB 161222 $0.50)
73	Current Nickel-Base High-Temperature Alloys, November 17, 1960, (PB 161223 $0.50)
74	Joining of Tungsten, November 24, 1960, (PB 161224 $0.50)
75	Review of Some Unconventional Methods of Machining, November 29, 1960
76	Production and Availability of Some High-Purity Metals, December 2, 1960
77	Rocket Nozzle Testing and Evaluation, December 7, 1960
78	Methods of Measuring Emittance, December 27, 1960
79	Preliminary Design Information on Recrystallized Mo-0.5Ti Alloy for Aircraft and Missiles, January 16, 1961
80	Physical and Mechanical Properties of Some High Strength Fine Wires, January 20, 1961
81	Design Properties as Affected by Cryogenic Temperatures (Ti-6Al-4V, AISI 4340, and 7079-T6 Alloys), January 24, 1961
82	Review of Developments in Iron-Aluminum-Base Alloys, January 30, 1961
83	Refractory Metals in Europe, February 1, 1961
84	The Evolution of Nickel-Base Precipitation-Hardening Superalloys, February 6, 1961
85	Pickling and Descaling of High-Strength, High-Temperature Metals and Alloys, February 8, 1961
86	Superalloy Forgings, February 10, 1961
87	A Statistical Summary of Mechanical-Property Data for Titanium Alloys, February 14, 1961
88	Zinc Coatings for Protection of Columbium from Oxidation at Elevated Temperatures, March 3, 1961

LIST OF DMIC MEMORANDA ISSUED
(Continued)

DMIC Memorandum Number	Title
89	Summary of Present Information on Impact Sensitivity of Titanium When Exposed to Various Oxidizers, March 5, 1961
90	A Review of the Effects of Starting Material on the Processing and Properties of Tungsten, Molybdenum, Columbium, and Tantalum, March 13, 1961
91	The Emittance of Titanium and Titanium Alloys, March 17, 1961
92	Stress-Rupture Strengths of Selected Alloys, March 23, 1961
93	A Review of Recent Developments in Titanium and Titanium Alloy Technology, March 27, 1961
94	Review of Recent Developments in the Evaluation of Special Metal Properties, March 28, 1961
95	Strengthening Mechanisms in Nickel-Base High-Temperature Alloys, April 4, 1961
96	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, April 7, 1961
97	Review of Recent Developments in the Technology of Columbium and Tantalum, April 10, 1961
98	Electropolishing and Chemical Polishing of High-Strength, High-Temperature Metals and Alloys, April 12, 1961
99	Review of Recent Developments in the Technology of High-Strength Stainless Steels, April 14, 1961
100	Review of Current Developments in the Metallurgy of High-Strength Steels, April 20, 1961
101	Statistical Analysis of Tensile Properties of Heat-Treated Mo-0.5Ti Sheet, April 24, 1961
102	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, April 26, 1961
103	The Emittance of Coated Materials Suitable for Elevated-Temperature Use, May 4, 1961
104	Review of Recent Developments in the Technology of Nickel-Base and Cobalt-Base Alloys, May 5, 1961
105	Review of Recent Developments in the Metallurgy of Beryllium, May 10, 1961
106	Survey of Materials for High-Temperature Bearing and Sliding Applications, May 12, 1961
107	A Comparison of the Brittle Behavior of Metallic and Nonmetallic Materials, May 16, 1961
108	Review of Recent Developments in the Technology of Tungsten, May 18, 1961
109	Review of Recent Developments in Metals Joining, May 25, 1961
110	Glass Fiber for Solid-Propellant Rocket-Motor Cases, June 6, 1961
111	The Emittance of Stainless Steels, June 12, 1961
112	Review of Recent Developments in the Evaluation of Special Metal Properties, June 27, 1961
113	A Review of Recent Developments in Titanium and Titanium Alloy Technology, July 3, 1961
114	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, July 5, 1961
115	Review of Recent Developments in the Technology of Columbium and Tantalum, July 7, 1961